11 Complications of Other Peripheral Nerve Blocks

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This chapter will discuss peripheral nerve blocks (PNBs) of the lower extremity. There are relatively few reports about complications associated with the use of PNBs in general and also about the mechanisms of injury after nerve blockade and methods to prevent them.

There is a general agreement about the benefits of PNBs, including preservation of consciousness, hemodynamic stability, postsurgery analgesia, early discharge of the patient, and limited sensory and motor blockade. Lower extremity blocks are very useful techniques to be familiar with and apply, because they provide excellent postoperative pain relief and have a very low incidence of complications, varying between 0%–5%.[1]

A complication is an undesired event subsequent to a medical treatment that may or may not be reversible, has different grades of severity, and is not always preventable. It differs from an adverse reaction, which may be defined as an undesired event ranging from a simple discomfort to damage limiting daily activities of the patient, but generally preventable.

PNBs of the lower extremity have never been as widely taught or used as other techniques of regional anesthesia. This may be attributable to the impossibility of anesthetizing the entire lower extremity with a single injection. Furthermore, injections required to perform a block of the lower extremity are generally deeper than those required for upper extremity block.[2]

Over the past decade, several developments have led to a growing interest in PNBs of the lower extremity; these changes in clinical practice are mainly the result of reports of new complications associated with central neuraxial techniques, e.g., transient neurologic symptoms associated with spinal anesthesia, an increased risk of epidural hematoma with the introduction of new antithromboembolic prophylaxis regimens, and to the positive effects on rehabilitation outcomes associated with continuous lower extremity PNBs.[2] PNBs are often incorrectly blamed for nerve injuries that are more likely caused by tourniquet pressure, surgical intervention, or poor positioning of the patient.

Epidemiology of Complications of Peripheral Nerve Blocks of the Lower Extremity

A great deal of literature has been devoted to the techniques of regional anesthesia. The clearest picture of regional anesthesia complications comes from the ASA Closed Claims Project database.[3] The ASA Closed Claims analysis permits a structured

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evaluation of adverse anesthetic outcomes collected from the closed anesthesia malpractice insurance claim files.

In the 1990s, 308 claims in the United States were associated with regional anesthesia, versus 642 associated with general anesthesia. In this decade, the percentage of claims for patient death (10%) continues its steady decrease from more than 20% in the 1970s to 13% in the 1980s.[4]

In the same decade, we also observed a significant increase in the percentage of claims arising from pain management in nonoperative settings,[5] where anesthetic blocks accounted for 84% of the ASA Closed Claims Project database (neuraxial blocks 55%, sympathetic blocks 16%, axial nerve blocks 15%, other blocks 9%).[4]

Another study from the ASA Closed Claims Project database evaluated injuries associated with regional anesthesia in the 1980s and 1990s in surgical settings: PNBs accounted for 13% of all regional anesthesia claims; death or brain damage was associated with 11% of peripheral block claims and included mostly interscalene, axillary, and intravenous regional blocks. Damaging events in these claims were related mostly to block technique, wrong dose or wrong drug, inadequate ventilation, delayed absorption of local anesthetic, and difficult intubation. Permanent nerve damage was associated with 29% of PNB claims (according to frequency: brachial plexus damage, median nerve, ulnar, radial, femoral/sciatic) and temporary injury with 58% of claims.[6] Auroy et al.[7] have studied complications of regional anesthesia over 30 geographical regions, including overseas French departments. Every hospital or private clinic was surveyed during 3 consecutive days, from February 1, 1996 to January 31, 1997. The aim of this survey was to identify three types of information: main characteristics of patients undergoing anesthesia, anesthesia (urgent or elective, starting and ending time, general or regional anesthesia, airway management, pharmacologic agents), and procedure. The annual rate of anesthetic procedures in the whole population was 13.5 anesthesia procedures per 100 inhabitants, and the number of anesthetic procedures for surgery was 9.5/100. Regional anesthesia was performed in 21% of cases, and in 2% of cases a combined technique of regional and general anesthesia with intravenous or volatile agents was performed. Orthopedic surgery was the most common surgery, accounting for the majority of regional anesthesia procedures. The two major findings of this study were that anesthesia has both increased and changed since 1980: the number of anesthetic procedures increased by 120% from 1980 to 1996 in France, and there was a consistent growth in the number of anesthetics performed in the elderly. There was an increase in the number of regional anesthetics performed.

There was a 16-fold increase in the use of plexus/nerve blocks reported since the 1980s. In the French survey from Clergue and colleagues,[8] 21,278 PNBs were performed in the 5-month period of the study: they estimated the potential for serious complications per 10,000 PNBs and found 0–2.6 deaths, 0.3–4.1 cardiac arrests, 0.5–4.8 neurologic injuries, 3.9–11.2 seizures, and 0.5–4.8 radiculopathy.

In a more recent analysis in 2002 from Auroy et al.,[9] of a total of 158,083 regional blocks performed in the 10-month period of the study, anesthesiologists reported 56 serious complications related to regional anesthesia. The study estimated an incidence of major complications after the 394 posterior lumbar plexus blocks higher than expected and higher than that reported with other PNBs (25.4/10,000 cardiac arrests, 50.8/10,000 respiratory failures, 25.4/10,000 seizures, and 25.4/10,000 deaths).

Apart from specific considerations, the study estimated that the total incidence of severe complications after regional blocks to be lower than 5/10,000. It is rare for serious cardiac and neurologic complications to occur in association with regional anesthesia. Published information primarily involves retrospective studies or case reports[7]; moreover, large numbers of patients are required to compare the incidence and characteristics of serious critical events.

There is a paucity of reports of complications specifically attributable to PNBs of the lower extremity, which is really evident if compared with reports about PNBs of the upper extremity. Nevertheless, according to some authors, this is likely related to their less common application, rather than to the inherent safety of the techniques.[2] According to Ben-David[4] in his overview about complications of neuraxial and PNBs, we should consider four categories: first, psychogenic reactions such as anxiety and agitation, vasovagal reactions, severe bradycardia, hypotension, loss of consciousness, and even seizures. These problems can be prevented with the judicious use of sedation, together with carefully monitoring the patient. The second group of coincident complications includes those injuries occurring during anesthetic block completely unrelated or indirectly related to the block itself. The third group of complications is those resulting from trauma from the technique itself, and finally, we must consider untoward effects of the local anesthetic and adjuvant drugs themselves. These two latter categories comprise the most frequent complications of both peripheral and neuraxial regional anesthesia.

We have evaluated two large groups of complications related to PNBs: the first includes the intrinsic complications directly attributable to the anesthetic technique itself; the second category includes extrinsic complications not strictly related to the PNB performed.

In the first category we include:

1. Nerve injury
2. Systemic toxicity
3. Hematoma and its relation to deep vein thrombosis prophylaxis
4. Infection

In the second category, we consider complications that can occur after surgery and that might be caused by surgery itself and not by the anesthetic technique:

1. Stretching of the nerves because of patient positioning
2. Ischemic nerve injury because of tourniquet pressure
3. Surgical factors leading to neuropathy

We also stress another important theme about complications of lower extremity PNBs, and that is the risk of failure in performing these blocks. This is a very important part of this discussion for both expert practitioners and those learning the techniques.

Failure in Performing Peripheral Nerve Blocks of the Lower Extremity

Failure of anesthesia is not strictly a complication of PNBs. However, it can lead to serious complications.[10] Over the years, the use of regional anesthesia has been confronted with the need to produce an adequate level and degree of blockade in an acceptable period of time with a safe dose of local anesthetic. The nerve blockade has to be complete, must have a desired duration of action, and must be reproducible.[11] The purpose of any regional anesthetic technique is to deposit a quantity of local anesthetic close enough to the nerve to block nerve transmission in that nerve. In anesthetic practice, this is usually performed percutaneously.[12] Because we usually use a blind approach, the success rate varies.

The failure rate with PNBs depends on the type of block performed: a success rate greater than 95% is frequently reported for ophthalmic anesthesia,[10] whereas a failure rate of up 30% is reported with brachial plexus anesthesia[13](Chapter 8).

In view of the risk of failure of regional anesthesia, the anesthesiologist is always expected to have an alternative plan of anesthesia including general anesthesia. The efficacy of PNBs is estimated to range from 70% to 85%. There are a number of methods available to increase success rates with PNBs, including electrical nerve stimulation (ENS) techniques, multiple injection techniques, percutaneous electrode guidance (PEG) techniques, and imaging techniques (ultrasonography).

ENS, Multiinjection Technique, PEG

Not all nerve fibers within a peripheral nerve will be stimulated by a given electric current. In general, the Aα motor fibers and the smaller C fibers subserving touch and pain respond at different current levels: the motor fibers can be stimulated with a lower intensity of current. This means that if a nerve is stimulated at just above its threshold, the effect will be twitching in the muscles that it supplies without pain or sensation in the dermatome. This phenomenon is the basis for the use of ENS in regional anesthesia.[12]

In the past, PNBs were usually performed using paresthesias, blind approaches, or transarterial methods, but these methods were associated with a high risk of intraarterial injection of drugs, pseudoaneurysm, and hemorrhage. If the act of eliciting a paresthesia represents traumatic contact with nerve fibers, it may be wise to avoid it. There is some evidence in the literature that most cases of nerve injury following spinal anesthesia and all cases after epidural and PNBs were associated with paresthesias during needle placement or pain during injection[7]; however, this matter is still controversial and contradictory data exist.

One important advantage of the nerve stimulator technique is that it is an objective method of confirming the needle–nerve contact. This is not true when using the paresthesia method, which is purely subjective.[1] The use of a nerve stimulator may reduce the potential risk for posttraumatic nerve complications, hemorrhage, and toxicity. It increases the specificity of peripheral nerve blockade and the reliability of the technique. According to many authors, the major benefits of using a nerve stimulator is that patients have a clearer understanding of your goals as opposed to the paresthesia method. Nevertheless, a study from Auroy and colleagues[9] in 2002 reported the occurrence of neurologic complications even after the use of a nerve stimulator for PNBs.

It has been suggested that the use of ENS alerts one to the proximity of the needle to the nerve, thereby reducing the chance of traumatic injury to the nerve. Despite this theory, there are reports of permanent nerve injury, including spinal cord injury following electrostimulation-guided nerve block.

In particular, caution should be exercised when stimulation is obtained with currents lower than 0.2 mA. According to Hadžić,[1] stimulation with such low current intensity is often associated with paresthesia on injection, perhaps suggesting an intraneural placement of the needle. In this scenario, it is recommended to withdraw the needle until a motor response is obtained at a current of 0.2–0.5 mA.

A multiple-injection technique, using electrical stimulation methods, has also been suggested to reduce the failure rate in PNBs. The rationale for this technique is that if there are many nerves to be blocked, it is possible to block them one by one. As Fanelli[14] observed, nerve stimulators allow a multiple injection technique by eliciting different muscular twitches during block placement. This technique provides effective PNBs with volumes of local anesthetic solution markedly less than those usually reported, without increasing the risk for nerve injury.[15] Use of a multiple injection technique with a nerve stimulator may increase the safety of PNBs by reducing the required volumes of local anesthetic solution, as well as the volume of anesthetic injected at each site.[16]

In 1999, Fanelli and colleagues[15] collected information from 28 departments of anesthesia in Italy that routinely used nerve stimulator and multiple injection techniques when performing PNBs. The study involved either upper or lower limb blockade. They excluded patients with a history of neuropathy, diabetes, or those who required surgical procedures involving nerve structures. The results showed no case of systemic adverse reaction and a failure rate similar in the three groups with a mean value of approximately 7%. The success rate reported was greater than 90%, and higher than that previously reported.[17]

Although it has been demonstrated that the multiple injection technique allows both a faster onset time and a greater success rate, most anesthesiologists are concerned about the theoretical risk of needle trauma or intraneural injection. This observational study by Fanelli, involving a multiinjection technique, demonstrated an incidence of local neurologic injury equal to that reported by Selander et al.[18] using a single injection technique (1.9%, >500 blocks). Fanelli et al.[15] concluded that the withdrawal and redirection of the needle was not associated with an increased incidence of nerve injury.

The third technique mentioned is PEG, or percutaneous electrode guidance. This is a noninvasive technique for prelocation of peripheral nerves to facilitate peripheral plexus or nerve block.

Imaging Techniques: Ultrasound Guidance

Blind insertion of needles to block neural targets is known to result in complications. The use of ENS does not guarantee success of PNBs. The rationale for the use of imaging techniques such as ultrasonography in regional anesthesia is that one can see the advancing needle approaching the nerve. Furthermore, one can also see the spread of local anesthetic solution during the injection and make adjustments if necessary.[19]

The use of ultrasound guidance in regional anesthesia was first reported by La Grange et al.[20] in 1978: they performed supraclavicular brachial plexus blocks with the help of a Doppler ultrasound blood-flow detector. According to Greher et al.[21] and Peterson,[22] ultrasound will be the guidance technique of the future, even if the transition from the conventional technique of nerve stimulation will take another 10 years or even longer to complete. Over the past decade, Marhofer and colleagues[19] have studied the use of ultrasound guidance in order to significantly improve the quality of PNBs and to reduce complications such as intravascular injection and intraneuronal injection.

The potential advantages of ultrasonography in regional anesthesia may be direct visualization of nerve, direct visualization of anatomic structures, direct and indirect visualization of the spread of the local anesthetic, avoidance of side effects, avoidance of painful muscular contractions during nerve stimulation (in cases of fractures), reduction of the dose of local anesthetic, faster sensory onset time, longer duration of blocks, and improved quality of block.

Marhofer et al.[19] have performed more than 4000 nerve blocks under direct ultrasound guidance in a period of 10 years, and they found that the success rate improved up to 100% with significant improvements obtained in terms of sensory and motor onset times.

What type of equipment do we need to effectively use ultrasonography in regional anesthesia? It is evident that the higher the frequency, the higher the resolution, but the smaller the penetration depth. Most nerve block applications require frequencies in the range of 10–14MHz.[19]

Peripheral nerves can appear both as hypoechoic and hyperechoic sonographic images when using ultrasound guidance.[23,24] This different appearance depends on the size of the nerve, the sonographic frequency used, and the angle of approach of the ultrasound beam. Marhofer et al.[19] performed most of the ultrasound-guided peripheral blocks on a transversal scan: the nerves appeared as multiple round or oval hypoechoic areas encircled by a relatively hyperechoic horizon (the fascicles of the nerves) in a hypoechoic background (connective tissue between neuronal structures). Tendons appear as multiple hyperechoic continuous lines, which gives them a fibrillar pattern (this is why peripheral nerves are said to have a fascicle pattern, instead); that is how they can be distinguished from nerves. The smallest fascicles cannot be visualized by ultrasound. The fascicular pattern is typical of large peripheral nerves and not of small nerves such as the superior laryngeal nerve.

Most peripheral nerves can be visualized over their entire course; only bony structures or large vessels can limit the visualization of nerves by ultrasound. During the performance of PNBs, the needle itself generates a dorsal acoustic shadow which can be identified as a hypoechoic structure. Once the needle is optimally placed, the local anesthetic can be observed spreading under direct sonographic visualization. The transverse approach allows one to maintain the same approach used when performing PNBs with nerve stimulation and also allows one to use the shorter insertion pathway compared with the longitudinal probe approach.

If guided by nerve stimulation, the three-in-one block has a failure rate of up to 20% when using nerve stimulation.[25] This block is ideally suited for ultrasound guidance with a high-frequency ultrasonographic probe (10MHz or even more). The puncture is performed 1cm distal to the probe. This technique can significantly improve the success rate of the 3-in-1 block. It reduces onset time, improves the quality of all three blocks, avoids complications,[26] and reduces the quantity of local anesthetic required.[27]

The reported incidence of success rate of lumbar plexus block never exceeds 80% irrespective of the approach used.[28] The ideal ultrasonographic frequency for this block is 5MHz according to Kirchmair et al.[29], who collected 20 volunteers and succeeded in visualizing the lumbar paravertebral region but not the lumbar plexus. Using additional computed tomographic scans on cadavers, they demonstrated that the needle could be accurately placed in the psoas compartment in 98% of cases.[30] Despite these good results, psoas compartment blocks are difficult to perform under ultrasound guidance because of the relative depth of the plexus.[29] A good success rate can be achieved with sciatic nerve block when the block is performed with ENS (87%–97%),[31,32] presumably because of its large dimension. Ultrasound guidance can reduce the risk of intraneural puncture, increase the success rate, allow the anesthetist to detect the sciatic nerve bifurcation, and allow the block of the posterior femoral cutaneous nerve.[19] The first problem with this approach is that the sciatic nerve has anisotropic behavior so that the beam has to be perpendicular to the nerve. The nerve is embedded in muscles which reduce the quality of the ultrasonographic image. In the popliteal region, a 5- to 12-MHz linear probe can be used to aid in its visualization. Ultrasound-guided imaging should be performed in the subgluteal region, where the nerve is relatively close to the skin surface. The distal branches can also be visualized distal to the head of the fibula; in addition, high-frequency linear probes can be used to visualize other subcutaneous branches.[19]

Some preliminary experiences have also been reported in children (Chapter 13). In this patient population, PNBs are usually performed under general anesthesia[33]; therefore, ultrasound is especially welcome as a guidance technique in this patient group. Children can be managed with high-frequency linear ultrasound probes because their nerves are very close to the skin. Ultrasound guidance has been routinely used in children by Marhofer et al.[19] for ilioinguinal nerve block, three-in-one block, sciatic block, femoral block, and brachial plexus block with good results.

Intrinsic Complications

Nerve Injury

For practical purposes, we can define a nerve injury as a clinical, anatomic, or laboratory finding consistent with damage to discrete elements of the peripheral nervous system.[34] According to Liguori,[35] the importance and severity of a nerve injury depends on three factors: first, the severity and quality of the sensory or motor deficit (from dysesthesia to severe pain, numbness and weakness interfering with daily activities); second, the duration of clinical symptoms (from transient phenomena for most nerve injuries to long-term or permanent injuries); third, the patient in whom the nerve injury occurs.

The incidence of nerve injury has been evaluated by many authors.[7,15,36–41] Liguori[35] noted that the wide range in the incidence of nerve injury reported depends on how accurate the anesthesiologist's investigation is, whether the study is prospective or retrospective, and the timing of the follow-up. The range varies from 0.004%[7] to 14%[40]: the closer investigators look at nerve injury after surgery, the more frequently problems are encountered. Although there are relatively few reports on anesthesia-related nerve injury associated with the use of PNBs, it may be that the incidence is underestimated. The less frequent clinical application of lower extremity PNBs may be the reason that there are even fewer reports of anesthesia-related nerve injury associated with lower extremity PNBs.[2]

Neurologic complications after lower extremity PNBs can be the consequence of the anesthetic technique itself including needle trauma, local anesthetic neurotoxicity, ischemic injury secondary to pressure and volume of local anesthetic or added vasoconstrictors, hematoma, or vascular injury. However, injuries can also be related to intraoperative factors, including surgical trauma and positioning, tourniquet injury, and postoperative factors, including swelling and positioning.

According to some authors, the first way to minimize the chance of causing a nerve injury is to maintain an awake and alert patient when performing PNBs, no matter what technique is used.[42] Nevertheless, judicious use of sedation can help the anesthesiologist in performing the block, allows better patient acceptance, and will allow the patient to warn the anesthesiologist when they experience paresthesias or pain on injection. Obviously, this goal cannot be achieved in pediatric patients.

Some case reports suggest that pain may be absent as a warning sign in pending nerve injury. However, the combination of premedication with sedatives and analgesics, along with the neuronal blocking properties of local anesthetics, may render pain on injection as the sole indicator of intraneural injection unreliable.[1]

Injuries to peripheral nerves after intrafascicular injection of therapeutic and other agents are well documented. Nerve injury following intraneural injection varies from minimal damage to severe axonal and myelin degeneration, depending on the agent injected and dose of the drug used. Nonetheless, several studies have documented that regardless of the agent used, intrafascicular injection is the main determinant of nerve injury. Experimental evidence suggests that such injections may be associated with a resistance to needle advancement and an increased pressure on injection of local anesthetic.[1]

Local anesthetics are innocuous when injected perineurally in appropriate quantities and concentrations, whereas high concentrations are known to permanently damage neural tissue in some cases. Kalichman et al.[43] demonstrated a concentration-dependent increase in neural edema, lipid inclusions, fiber injury, and Schwann cell injury using extraneural injection of various local anesthetic agents on rat sciatic nerve. Intraneural injection of local anesthetics, particularly when associated with epinephrine, can produce significant nerve injury. Concurrent injury, ischemia, or disease may also predispose to neurotoxic injury.[44,45]

There is no evidence in the literature that a prolonged duration of blockade or a continuous block can worsen the nerve damage caused by the local anesthetic.[46] Local anesthetic toxicity also extends to muscles and includes focal myonecrosis with regeneration occurring over several weeks.[47] Myotoxicity is enhanced by the use of epinephrine.[48]

According to Faccenda and Finucane,[10] substances added to local anesthetics may also cause local toxicity; e.g., a change in the preservative of chloroprocaine resulted in several cases of cauda equina in 1970s in the United States, EDTA (ethylenediaminetetraacetic acid) added to the same compound caused severe back pain in some patients following epidural anesthesia, and 5% hyperbaric lidocaine has been linked with transient neurologic symptoms following spinal anesthesia.

As Hadžić describes,[1] neurologic injuries resulting from an intraneuronal injection may be related to several factors, including direct needle trauma with perforation of the perineurium and other nerve sheaths, physical disruption of the nerve fibers, and disruption of the neuronal microvasculature, with the consequent intraepineural or intrafascicular hematoma and nerve ischemia. Because the perineurium is a tough and resistant tissue layer, an injection into this compartment or a fascicle can cause a prolonged increase in endoneurial pressure, exceeding the capillary perfusion pressure. This pressure in turn may result in endoneural ischemia. The addition of a vasoconstrictor and the application of a tourniquet over the site of nerve blockade will inevitably result in an additional decrease in blood supply to the nerve. The combination of all these factors contributes to neuronal ischemia and increases the risk of neurologic injury. However, in patients undergoing lower extremity surgery, the addition of epinephrine to the local anesthetic solution used in combined femoral and sciatic nerve blocks was not shown to be a risk factor for the development of post–nerve block dysfunction.[15]

There is no clear-cut algorithm for the management of a postoperative nerve injury. According to Liguori,[35] symptoms are often first noted and referred by surgeons during the first postoperative visit; these symptoms are usually blamed as consequences of the regional anesthetic technique. For the majority of these patients complaining about complications, a single call by the anesthesiologist is enough to reassure the patient. Most frequently, residual dysesthesias and hypoesthesias are reported and in these cases simple reassurance is all that is required.

Symptoms of neurologic injury resolve in 4–6 weeks in 92%–97% of patients and in more than 99% in 1 year.[39,40] If symptoms interfere with daily activities or persist beyond a few weeks, neurologic consultation and testing should be considered.[35]

According to Hadžić,[1] these are the measures to take into account to prevent nerve injuries:

1. Aseptic technique: Most nerve block techniques are merely percutaneous injections. However, infections are known to occur and can result in significant disability. Because this complication is almost entirely preventable, every effort should be made to strictly adhere to aseptic technique.
2. Short bevel insulated needles: The short bevel design helps prevent nerve penetration. Insulated needles are now widely available and result in much more precise needle placement when nerve stimulator is used. A contrary opinion is expressed in Chapter 5.
3. Needles of appropriate length for each block procedure. In addition, needles of appropriate length can be advanced with far greater precision than excessively long needles.
4. Needle advancement: During needle localization, advance and withdraw the needle slowly. Keep in mind that nerve stimulators deliver a current of very short duration (usually 1–2 Hz) and no current is delivered between the pulses. Fast insertion and withdrawal of the needle may result in failure to stimulate the nerve because the needle may pass nearby, or even through, the nerve between the stimuli without eliciting nerve stimulation.
5. Fractionated injections: Inject smaller doses and volumes of local anesthetics (3–5 mL) with intermittent aspiration to avoid inadvertent intravascular injection. Always observe the patient during the injection of local anesthetic because negative aspiration of blood is not always present with an intravenous injection. This approach may allow detection of the signs of local anesthetic toxicity before the entire dose is injected.
6. Accuracy of the nerve stimulator: Always make sure that the nerve stimulator is operational, delivering the specified current, and that the leads are properly connected to the patient and the needle.
7. Avoidance of forceful, fast injections: Forceful, fast injections are more likely to result in channeling of local anesthetic to the unwanted tissue layers, lymphatic vessels, or small veins that may have been cut during needle advancement. Such injections may result in massive channeling of the local anesthetic into the systemic circulation, with the consequent risk of severe central nervous system and cardiac

toxicity. Forceful, fast injections under excessive pressure may also carry more risk of intrafascicular injection. Limit the injection speed to 15–20 mL/minute.

8. Avoidance of injection under high pressure: Intrafascicular needle placement results in higher resistance (pressure) to injection because of the compact nature of the neuronal tissue and its connective tissue sheaths. Always use the same syringe and needle size to develop a "feel" during the injection. As a rule, when injection of the first milliliter of local anesthetic proves difficult, the injection should be abandoned and the needle completely withdrawn. Check for patency before reinserting.

9. Avoidance of paresthesia on injection: Severe pain or discomfort on injection may signify intraneuronal placement of the needle and should be avoided. This should not be confused with a normal mild "paresthesia-like" symptom, frequently reported by patients when the needle is placed in the immediate vicinity to the nerve. Keep in mind that published case reports suggest that the absence of pain on injection alone does not guarantee that the needle is not placed intraneurally. Absence of pain and abnormal resistance to injection should be documented in the anesthetic record after each block procedure.

10. Choose your local anesthetic solution wisely: Always choose a shorter-acting (and less toxic) local anesthetic for short procedures in which long-lasting postoperative analgesia is not required. Local anesthetic toxicity is the most common complication with neuronal blockade, and it is much safer when this occurs with chloroprocaine or lidocaine than with bupivacaine.

11. Blocks in anesthetized patients: Blocks in anesthetized patients should be avoided or at least be an uncommon practice. When it is necessary to place blocks in anesthetized patients, this should be done only by practitioners with substantial experience with the planned technique. Such cases should *never* be considered "teaching" and one should carefully note the reasons for doing the block in these circumstances.

12. Repeating blocks after a failed block: It should be avoided whenever possible. When indicated, it should be done only by those with substantial experience in the planned technique.

Systemic Toxicity (Chapter 4)

Although the use of large quantities of local anesthetic solutions improves the success rate and predictability of PNBs, it may also increase the risk of local anesthetic-related systemic toxicity. The risk of systemic toxicity is reduced when the minimum effective dose of local anesthetic is used. The clinical relevance of this assumption further increases when a combination of different nerve blocks is used as in lower limb procedures.[16]

The potential for systemic local anesthetic toxicity would seem to be much higher for lower extremity PNBs compared with other regional techniques: for instance, combined femoral and sciatic nerve blocks require large doses of local anesthetic to effectively anesthetize the entire lower extremity.[2] However, there are only a few case reports of local anesthetic toxicity associated with these blocks and some authors report no cases of systemic toxicity after PNBs of the lower extremity. Fanelli and colleagues[15] evaluated 2175 femoral sciatic combined blocks, with no systemic toxic reactions reported.

The safety of lower extremity PNBs seems to vary depending on the individual nerve block. There are no cases of systemic toxicity following popliteal sciatic block, whereas there are several reports of severe toxicity following lumbar plexus blocks and proximal sciatic blocks.[9,49–52]

In a study by Auroy and colleagues,[7] seizures were reported in 23 patients among 103,730 who underwent regional anesthesia in the 5-month period of the study, but up to 16 seizures were PNB related and all were preceded by minor auditory symptoms and complaints of metallic taste. In this study, seizures occurred more frequently after PNBs than after other techniques and occurred five times more frequently than with epidural anesthesia. In those patients who experienced seizures, a larger volume of lidocaine 2% or bupivacaine 0.5% was injected for PNBs than for epidural (41 ± 14 versus 15 ± 4mL).

The incidence of seizures associated with regional anesthesia ranges between 1/1000 to 4/1000, but few reports are available. Brown et al.[53] collected cases of seizures related to brachial plexus blocks, epidural anesthesia, and caudal regional anesthetics from 1985 to 1992 and their series included 25,627 patients. Seizures occurred in 26 patients. The frequency of seizures associated with the use of regional anesthesia varied significantly among anesthetic types, with caudal > brachial > epidural, with bupivacaine as the most frequent agent related to seizures. None of the 26 patients who had seizures required hemodynamic support more intense than intravenous ephedrine or atropine, coupled with delivery of supplemental oxygen and controlled ventilation. None of these patients required epinephrine or antiarrhythmic therapy; furthermore, none of these patients required an extra length of stay in the postanesthesia care unit, compared with patients undergoing similar procedures.

Auroy et al.[9] in 2002 reported one case of irreversible cardiac arrest after a posterior lumbar plexus block in a series of 158,083 regional blocks. This patient had a T2 sensory level and bilateral mydriasis was noted immediately before the arrest. They were aware that intrafascicular proximal spread of the local anesthetic can occur proximally toward the spinal cord and result in neuraxial blockade. This is a particular concern with block techniques that involve needle placement at the level of nerve roots, especially paravertebral blocks and psoas compartment block. Auroy and colleagues recommended that these cases required the same level of vigilance as that required for neuraxial block because of the high risk of complications. Details about diagnosis and management of systemic toxicity following local anesthetic injections are covered in detail in other chapters in this text (Chapters 4 and 8).

Hematoma

It has been noticed[2] that the psoas compartment approach to the lumbar plexus, the obturator nerve block, the parasacral, and classical approaches to sciatic nerve involve deep needle penetration. Vascular puncture during femoral nerve block placement has been reported to be as frequent as 5.6%.[54] However, few complications have been reported as a consequence of unintentional vascular puncture while performing femoral nerve block.[55]

Several investigators have documented hematoma as a complication occurring after psoas compartment block. To reach the lumbar plexus, the needle must transverse multiple muscles and other tissue layers. Moreover, lumbar plexus block is often used to provide anesthesia and analgesia in patients undergoing total hip replacement.[56] This kind of surgery requires and justifies prolonged thromboprophylactic treatment. The combination of anticoagulant administration together with blind needle puncture required for this block presents significant risk factors for the development of a hematoma.

In 2003, Weller and colleagues[57] described two cases of delayed retroperitoneal hematoma after lumbar plexus block. In one of these cases, the hematoma was diagnosed on postoperative day 4 even though it was evident that vessel trauma had occurred during catheter placement; in the other case, no apparent vessel trauma was noted during needle placement, but clinical symptoms of retroperitoneal hematoma occurred on postoperative day 3. Also, Aveline and Bonnet[58] in 2004 reported a similar case. They attempted to perform a lumbar plexus block in a patient. They advanced the needle in a cephalad direction twice after its insertion and, because they were unable to achieve the required end point, neither the aspiration test nor the injection was performed. The anesthetic technique was then changed to a fascia iliaca compartment block, but on postoperative day 17, a computed tomographic scan showed a retroperitoneal hematoma where the first block had been attempted.

In a previous case from Klein et al.[59] in 1997, a patient reported the same complication after lumbar plexus block. The patient was receiving enoxaparin at the time of anesthetic procedure and the block was performed successfully after several attempts. In the two cases reported by Weller et al.[57] and in the case reported by Aveline and Bonnet,[58] enoxaparin was administered 8 hours, 40 hours, and 14 hours, respectively, after placing the block. This means that the patients were not anticoagulated while receiving the block; however, they did receive anticoagulant therapy in the rehabilitation period and this contributed to the occurrence of hematoma.

These cases demonstrate the risk of significant, concealed bleeding from needle placement in an area that cannot be observed when anticoagulation is initiated after nerve block. In the case reports by Weller and colleagues,[57] the signs of substantial occult bleeding from lumbar plexus block were anemia and back pain without apparent neurologic deficits. Both patients required blood transfusion and prolonged hospitalization.

Infection

Infectious complications may occur with any regional anesthetic technique. However, those associated with neuraxial anesthesia are of greater concern because of their potentially devastating sequelae. Aromaa et al.[60] collected information on 170,000 epidural and 550,000 spinal blocks, and reported an overall incidence of infection after epidural and spinal anesthesia of 1.1/100,000 blocks. Nevertheless, Wang et al.[61] estimated the risk of epidural abscess after epidural analgesia as 1/1930 and of persistent neurologic deficit as 1/4343. The frequency of infection associated with PNBs still remains undefined to our knowledge. Some reports refer to bacteremia or localized infection after continuous PNBs,[62–64] but there is no report about long-term infectious complications or dysfunctions[65] and there are no case reports of infection after lower extremity PNBs performed with single injection.

Cuvillon et al.[64] reported on the incidence of bacterial complications associated with the use of continuous femoral nerve blocks. They evaluated 208 patients; 57% had positive bacterial colonization of the catheter at 48 hours postoperatively. Three patients had transitory symptoms of bacteremia that resolved with removal of the catheter, but no long-term complications occurred in these cases. Two case reports of psoas abscess requiring drainage and intravenous antibiotic therapy have been described in patients who received a continuous femoral nerve block.[63,66]

The suspected mechanism of infection after PNBs and, more widely, regional anesthesia is mostly the invasion by skin bacteria through a needle track, contaminated syringes, contaminated catheter hubs, or contaminated local anesthetics, hematogenous spread from distant foci, or breaches in sterile technique.[67]

Skin disinfection is crucial to prevent infection, although there is not yet a wide consensus on how to provide such an optimal skin antisepsis. Second, the role of antibiotic therapy is still controversial: it is still unknown whether concurrent antibiotic therapy is protective against clinically significant infections. However, anecdotal evidence still suggests this is true, especially during periods of extended neuraxial and peripheral catheterization.[65] Further investigations will be necessary to establish definitive recommendations regarding perineural catheter use and antibiotic administration. Handwashing still remains the single, most important component in antisepsis: gloves are not to be considered as a replacement for handwashing.[68]

According to Hebl and Horlocker,[65] while we wait for more detailed recommendations and guidelines, it seems that the advice our mothers gave us when we were small was true: "Wash your hands, scrub behind your ears, cover your mouth when you sneeze, and always wear clean clothes . . . because you never know"!

Extrinsic Complications

Stretching of the Nerves Because of Patient Positioning

PNBs are often blamed for causing nerve injury; however, neuropathy after abdominal or lower extremity surgery is not an uncommon event.[2] Postoperative neurologic complications may actually be more common after general and neuraxial anesthesia than after PNBs. Such injuries were thought to be caused mostly by compression or stretching of the nerves or plexuses during patient positioning after general anesthesia, whereas injuries to the lumbosacral plexus primarily occur after central neuraxial blockade. Cheney et al.[69] evaluated sciatic nerve injury claims in the Closed Claims analysis: 50% of claims were associated with the lithotomy or frog-leg operative positioning. Warner et al.[70] observed nerve injury to the obturator, lateral femoral cutaneous, and sciatic nerves associated with the lithotomy position. Gruson and Moed[71] found an association between deep hip flexion or extension in total hip arthroplasty (THA) and repair of acetabular fracture and femoral nerve palsy. The same finding has been reported by Slater and colleagues.[72] According to Warner et al.[70] and Slater et al.,[72] positioning nerve injuries are consistently related to the length of surgery.

Ischemic Nerve Injury Because of Tourniquet Pressure

In a study from Fanelli et al.,[15] the tourniquet inflation pressure was more predictive of postoperative neurologic dysfunction than the anesthetic technique used: tourniquet neuropathy is due to an increased risk of transient nerve injury, especially when comparing tourniquet pressures lower than 400mmHg with those higher than 400mmHg. Current recommendations for tourniquet use during surgery include the maintenance of a pressure no higher than 150mmHg above the systolic pressure and deflation of the tourniquet every 90–120 minutes.[73] Even following these recommendations, post-tourniquet neuropathy has been reported.[74,75]

Surgical Factors Leading to Neuropathy

Femoral neuropathy has been reported in association with operations that require deep pelvic exposure, such as acetabular fracture repair.[71] The incidence of nerve injury after ankle arthroscopy is 17%, according to Barber and colleagues[76]: The injury, in this kind of surgery, often involves the peroneal nerve because of its proximity to the dorsal arthroscopy portal.[77] Joint distension, excessive traction, extravasation of fluid during surgery, and the clinician's experience using the arthroscope are all factors associated with a higher risk of neuropathy specifically attributable to the surgical technique itself.

Residency Training Programs: How Training Influences the Use of Peripheral Nerve Blocks in Clinical Practice

The advantages of PNBs have resulted in a diffuse and growing interest in regional anesthesia. The many qualities of these techniques include increasing patient satisfaction, answering to the actual growing demand for cost-effective anesthesia, and assuring a favorable postoperative recovery profile.[78] Despite these advantages, there is a wide perception that PNBs are infrequently used in clinical practice over general and neuraxial anesthesia, especially PNBs of the lower extremity.[79]

From 1990 to 1994, Hadžić et al.[79] reviewed all the abstracts presented at five consecutive American Society of Anesthesia meetings: only 0.8% of these abstracts focused on PNBs and only 0.2% focused on PNBs of the lower extremity; in the same period, reviewing the abstracts presented at American Society of Regional Anaesthesia meetings, only 3.5% addressed the lower extremity PNBs.

Does the literature interest reflect clinical practice of regional anesthesia and, more specifically, the use of PNBs of the lower extremity? According to Hadžić et al.,[79] in the United States the majority of anesthesiologists performed at least some regional anesthesia techniques during the same period of the literature cited; nevertheless, half of them performed less than five PNBs per month. Even among those who consider regional anesthesia a substantial part of their clinical practice, the same trend persists. Regarding the major conduction blocks of lower and upper extremity usually performed, it has been noted that femoral, sciatic, or popliteal blocks represent just a small part of the clinical practice if compared with the use of PNBs of the upper extremity.

The possible explanation for this disparity is that lower extremity PNBs may be considered more technically demanding than upper extremity PNBs and multiple blocks are required to provide complete conduction block of the lower extremity. Moreover, neuraxial anesthesia is almost always an alternative option for regional anesthesia of the lower limb, whereas no other choice is available for regional anesthesia of the upper extremity. This may be the reason why even the majority of anesthesiologists who provide anesthesia in the ambulatory setting often prefer neuraxial anesthesia over PNBs of the lower extremity.

To discover the possible explanation of the phenomenon, we have to analyze the environmental factors that can influence the anesthetists' choice about PNBs of the lower extremity, first of all considering their exposure to PNBs techniques during residency training programs.

Even during the past decades of the 1970s and 1980s, surveys have already shown that regional anesthesia would be the anesthesiologists' first preference for their surgical patients, especially in emergent situations.[80,81] More recent surveys have repeatedly shown that this attitude continued and escalated in the 1990s.[78] Nevertheless, this preference does not always influence clinical practice and teaching programs as we could expect.

It is a public perception that the number of blocks performed by a resident anesthetist and the proficiency acquired during training are both strictly related to the use of a particular technique in clinical practice.[82] Maybe because of this tight association between resident education and clinical practice, large discrepancies among training programs were noted over the last decades in the United States. It has been noted that at least some anesthesiology teaching programs have failed in their teaching of regional anesthesia.[83]

Kopacz and Bridenbaugh[84] reported that the average resident in training in the United States used regional anesthesia in 30% of cases, and general anesthesia or minimal anesthetic concentration in 70% of cases; this means a significant increase in the use of regional anesthesia since 1980, but wide disparities between programs and individuals still remained all over the United States (the wide range goes from 3% to 60%).

Since the 1990s, numerous educational changes have occurred in training programs and several techniques have also been invented or reborn in regional anesthesia (midhumeral brachial plexus block, combined spinal–epidural, lateral popliteal nerve block, paravertebral block, psoas compartment block).[85] Because every change in practice is usually expected to have a positive or negative influence on the teaching of regional anesthesia, once more Kopacz[85] in 2002 tried to answer the question: "Is resident exposure to regional anesthesia currently sufficient to provide adequate training of these techniques?"

Considering the indications stated in 1990 by the residence review committee (RRC) for Anaesthesiology of the American Directory of Graduate Medical Education Program (ADGME) about the educational requirements of anesthesiology training programs, 90% of residents reach the requirements for spinal and epidural anesthesia, whereas the greatest deficiency occurs in the area of PNBs: approximately 40% of residents report having inadequate exposure.[85]

Looking more specifically at the type of regional anesthesia where residency programs have failed, PNBs of the lower extremity were the most undertaught. For instance, femoral and sciatic blocks were infrequently used, maybe because of the more experience needed to attain a high degree of success, despite their accepted reliability.[83]

According to Buffington et al.,[82] practitioners interviewed about their use of regional anesthesia reported that what really changes from residency to practice is the type of block performed: spinal and axillary blocks almost doubled, whereas the use of epidural and sciatic/femoral blocks decreased.

Nevertheless, it is clear that high users in practice had been high users in residency. Chelly et al.[86] observed that residents in programs with a specific PNB rotation are exposed to a greater number of PNB techniques than those who do not have such a rotation included in their curriculum.

To discover what could make the anesthetist choose that specific technique for his patients, Buist[87] collected questionnaires from practitioners in the United Kingdom in the 1990s. Most respondents to Buist's study cited better postoperative analgesia as the main advantage of regional anesthesia, then lower morbidity, more rapid recovery, and suitability for day cases; others most frequently quoted included the suitability of regional anesthesia for patients with lung disease and the reduction in blood loss when regional anesthesia is used. Extra time required to establish the block, poor patient acceptance, low success rate, fear of nerve damage, and lack of surgeon compliance were the disadvantages cited by anesthesiologists.[87]

As a consequence, training programs cannot be the only influence in the practice of regional anesthesia. Residents should also be taught how to control environmental factors in addition to the technical steps of performing a block, because time pressure, surgeon attitude, patient compliance, and logistical requirements discourage the use of regional techniques in practice.[82]

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